An Overview of Artificial Reefs Constructed In Southern British Columbia Prior to 1994

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AN OVERVIEW OF ARTIFICIAL REEFS CONSTRUCTED IN SOUTHERN BRITISH COLUMBIA PRIOR TO 1994

by

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ABSTRACT

Naito, B.G. 2001. An overview of artificial reefs constructed in southern British Columbia prior to 1994. Can. Manuscr. Rep. Fish. Aquat. Sci. 2583: vi + 40 p.

This report summarizes the physical and biological information available for artificial reefs constructed in southern British Columbia prior to 1994. Where possible, qualitative comparisons of the marine flora and fauna between artificial reefs having different physical design characteristics (reef material, reef water depth, current and wave activity, water quality, etc.) are provided.

RESUMÉ

Naito, B.G. 2001. An overview of artificial reefs constructed in southern British Columbia prior to 1994. Can. Manuscr. Rep. Fish. Aquat. Sci. 2583: vi + 40 p.

Ce rapport présente un résumé des données physiques et biologiques disponibles concernant les récifs artificiels construits dans le sud de la Colombie-Britannique avant 1994. On fait à chaque fois que possible des comparaisons qualitatives entre les biotopes marins (flore et faune) de récifs artificiels ayant différentes caractéristiques physiques (matériaux, profondeur de l'eau, activité des courants et des vagues, qualité de l'eau, etc.).

INTRODUCTION

A number of artificial reefs have been constructed in southern British Columbia over the past several years. The location of each of these artificial reefs is shown in Figure 1.

Most information on artificial reefs in southern British Columbia have not been formally published and, hence, have not been widely distributed. The main reason for the absence of formal publications is that the detailed assessment of artificial reefs is often very costly and time consuming, thus, preventing the collection of statistically valid quantitative information.

In order to document information on artificial reefs in southern British Columbia in a formal manner, this report will summarize the results of biophysical assessments and other information on several artificial reef projects constructed in southern British Columbia prior to 1994. This report will also attempt to relate the biological productivity and/or diversity of each artificial reef to each reef's physical design characteristics for those artificial reefs where biophysical information is available.

METHODS

In order to summarize existing physical and biological information for each artificial reef, as much information (mainly qualitative data) as possible was collected from various letters, memoranda, and consultant reports.

In summarizing the results of physical and biological assessments of each reef an attempt was also made to relate the biological productivity and/or diversity of each reef to their physical design characteristics (such as reef material, water depth, water current, water quality, bottom substrate, etc.).

Please note that this report briefly summarizes the physical and biological survey results of each artificial reef. For more detailed physical and biological information, please consult the appropriate reports listed after the results of each reef and in the bibliography. A summary of the physical characteristics of each reef is provided in Table 1.

While every attempt was made to document all artificial reefs created in southern British Columbia over the past several years, there may be artificial reefs which are unknown to the author or for which there is no information available and, hence, are not included in this report.

Figure 1. Location of Southern British Columbia

Figure 2. Location of Artificial Reefs Constructed In Southern British Columbia Prior To 1994

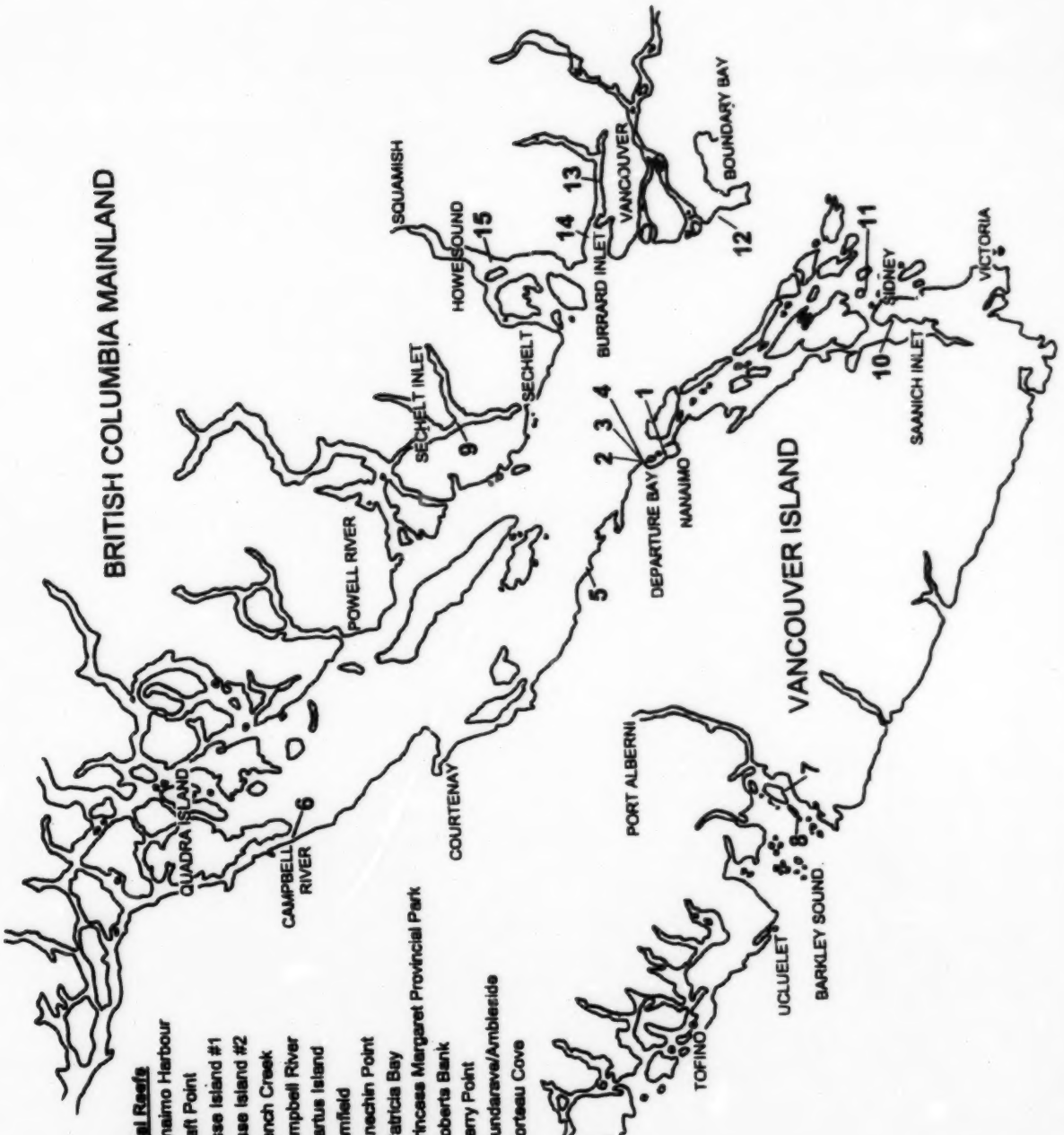

Table 1.
Summary Of Artificial Reefs Constructed In Southern British Columbia Prior To 1994

Reef Name / Location	Purpose Of Reef	Date Of Construction	Depth (m) L.L.W.	Bottom Substrate	Reef Material	Footprint (Sq.M.)	Maximum Length/Width (m)	Maximum Relief (m)	Comments
Nanaimo Harbour	Experiment	March 1984	6 - 7	Sand/Silt	Broken Concrete	1900	115 / 16.5	2.5	
Shaft Point Departure Bay	Compensation	February 1990	5 - 15	Sand/Silt	Broken Concrete	3120	110 / 26	2	
Jesse Island #1 Departure Bay	Experiment	May 1989	8	Sand/Silt	Tires	2 Reefs x 2.5 Each	2 Reefs x (1.5 / 1.5) Each	1.5	2 Separate Triangular Tire Units
Jesse Island #2 Departure Bay	Experiment	January 1989	8	Sand/Silt	Cinder Blocks	7	4.5 / 1.5	<1	
French Creek	Compensation	Spring 1984	9	Sand	Rock Rip Rap	2200	90 / 25	6	
Campbell River	Compensation	Spring 1986	9	Sand	Rock Rip Rap	1800	120 / 11	2.5	
Tzartus Island Barkley Sound	Compensation	Spring 1993	10	Silt/Sand	Rock Rip Rap	Unknown	Unknown	Unknown	
Barnfield Barkley Sound	Experiment	February 1978 August 1978	8 - 10	Sand	Cinder Blocks	10 Reefs x 1.5 Each	10 Reefs x (2.4 / 0.6) Each	0.9	10 Separate Cinder Block Reefs
Kunechin Pt Sechelt Inlet	Recreation	December 1992	27	Unknown	Ship	Unknown	Unknown	Unknown	2370 tonne Ship

Table 1. Continued

Summary Of Artificial Reefs Constructed In Southern British Columbia Prior To 1994

Reef Name / Location	Purpose Of Reef	Date Of Construction	Depth (m) L.L.W.	Bottom Substrate	Reef Material	Footprint (Sq.M.)	Maximum Length/Width (m)	Maximum Relief (m)	Comments
Patricia Bay Saanich Inlet	Experiment	1988	0 (Floating)	Silt	PVC Pipe	n/a	1.0 / 1.0	n/a	Floating Reef
Princess Margaret Provincial Park	Recreation	August 1991	22.5	Unknown	Ship	Unknown	53 / Unknown	Unknown	530 tonne Ship
Roberts Bank	Compensation	1983	10 - 15	Silt	Broken Concrete	Unknown	60 / Unknown	0.6 / 1.8	
Berry Point Burrard Inlet	Compensation	August 1992	10 - 15	Shell/ Sand	Rock Rip Rap & Broken Concrete	6 Reefs x 330 Each	10 / 11	5	
Dundarave/ Ambleside Burrard Inlet	Compensation	October 1989	10	Sand/ Shell	Rock Rip Rap	9500	600 / 16	Unknown	
Porteau Cove Howe Sound	Recreation	Commenced In 1972	9 - 20	Sand	Various See Text	See Text	See Text	See Text	See Text

RESULTS

NANAIMO HARBOUR

Description
A single distinct artificial reef was constructed in Nanaimo Harbour.

Purpose
The reef was constructed as an experiment to assess the biological productivity of artificial reefs.

Construction Date
March 1984.

Depth and Substrate
The reef was placed on a sand/silt substrate at a range of 6 to 7 metres depth L.L.W.

Reef Material
The artificial reef is made up of varying amounts of large broken concrete sewer pipe pieces, cinder construction blocks, and broken pieces of concrete decking/rubble. The total amount of material is estimated to be from 700 to 1,000 tonnes.

Placement Method
The reef material was transported to the site by barge and placed on the sea floor using a crane with clamshell bucket. Every effort was made to place the material to provide complex habitat with vertical relief. The reef was positioned so that it was beyond the casting range of a nearby breakwater float.

Reef Size
The artificial reef is estimated to be 115 metres in length and 16.5 metres wide. The maximum relief of the reef is about 2.5 metres although most of the reef has a relief of 1 metre or less. The total area or footprint of the reef is estimated to be 1900 square metres.

Monitoring
Physical and biological surveys of the artificial reef in Nanaimo Harbour were undertaken in March 1987, in January 1988, and in March 1988.

Survey Method
Information was collected from transects established across the width of the reef by divers using S.C.U.B.A. Fish enumeration was restricted to large game fish species, such as rockfish, greenling, lingcod, perch and large sculpins. In the March 1987 and January 1988 surveys, marine invertebrates and algae, known to be common to the geographical area surrounding the reef, were recorded using one of three qualitative abundance scales. In the March 1988 survey, data was collected only for conspicuous marine invertebrates and algae. Marine

invertebrates were enumerated while algae abundance was recorded on a percent coverage basis. During the March 1987 artificial reef survey comparisons were made to a nearby natural reef. There was no statistical analysis of any of the survey data collected.

Fish Survey Results

The majority of fish species observed on the reef included copper rockfish (Sebastes caurinus), striped perch (Embiotoca lateralis), pile perch (Rhacochilus vacca), lingcod (Ophiodon elongatus), and other greenling species from the Family Hexagrammidae (e.g. kelp greenling or Hexagrammos decagrammus). The estimated total fish on the reef was highest during the January 1988 survey (995), followed by the March 1987 (411) and March 1988 (140) surveys. The increase in estimated fish numbers in January 1988 over March 1987 was largely represented by increases in copper rockfish (S. caurinus) and pile perch (R. vacca). The decrease in fish numbers in March 1988 from January 1988 was largely due to a reduction in the number of copper rockfish (S. caurinus) observed and virtually no observations of greenling (Family Hexagrammidae) (except lingcod (O. elongatus) and pile perch (R. vacca). During the March 1987 survey, no fish were observed at the natural reef.

Invertebrate Survey Results

Invertebrate species diversity was determined only for the March 1987 and January 1988 surveys. Invertebrate diversity on the reef was estimated to be low (29 species in March 1987 and 21 species in January 1988) but abundant. Abundance estimates were conducted for the March 1988 survey. The most common invertebrate species observed included calcareous tubeworms (Serpula vermicularis), orange trumpet sponges (Isodictya quatsinoensis), plumose anemones (Metridium senile), sunflower stars (Pycnopodia helianthoides), jingle shells (Pododesmus cepio), acorn barnacles (Balanus glandula), coonstripe shrimp (Pandalus danae), and stalked hairy sea squirts (Boltenia villosa).

Algae Survey Results

During the March 1987 survey, only three algal species were observed with the most common being Rhodomenia spp., followed by Griffithsia pacifica, and Laminaria saccharina. L. saccharina was low in abundance and small in size (< 40 cm length) compared to the nearby natural reef. During the January 1988 survey, ten species were observed. The five most common species were the red algae Rhodymenia pertusa, Rhodymenia spp., and Callophyllis spp. and the kelps Agarum cribosum and L. saccharina. The A. cribosum individuals observed were composed of both adult (> 40 cm length) and juveniles (< 15 cm length). All L. saccharina plants were greater than 40 cm long with some plants being over 1 metre long. The cover of algal growth on the reef was estimated to be 15 to 20 percent. During the March 1988 survey, only conspicuous marine algae were recorded which included Rhodymenia spp., Callophyllis spp., Dilsea spp., and L. saccharina. In general, algal cover on the reef during the March 1988 survey was sparse.

Summary
The abundance of marine life (in particular, marine algae) on both artificial and natural reefs in Nanaimo Harbour may be limited by the low light conditions in the area during freshet in the Nanaimo River (Naito, 1988b). From previous S.C.U.B.A. dive inspections in Nanaimo Harbour, the author has noticed that at all times of the year the underwater visibility was observed to be lower in Nanaimo Harbour compared with areas of higher water circulation.

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SHAFT POINT - DEPARTURE BAY

Description
A single distinct artificial reef was constructed near Shaft Point in Departure Bay in Nanaimo, B.C.

Purpose
The reef was constructed by the Nanaimo Harbour Commission (NHC) for use as compensation for losses of fish habitat that may result from future development projects. The material for the reef became available as a result of the demolition of a building by the NHC located on their property. A few months after the main reef construction, the British Columbia Ferry Corporation added several scrap metal pieces (including steel piles) to the north end of the reef.

Construction Date
The main reef was constructed between January 24 and February 15, 1990. The addition of scrap metal pieces was made to the reef a few months after construction.

Depth and Substrate
The reef was placed on gently sloping sand/silt substrate in 5 metres to 15 metres water depth (local low water).

Reef Material
The artificial reef is mainly made up of broken concrete slabs 0.3 to 1.0 metre in diameter and 0.2 metres thick from the demolition of a concrete building. There

are some pieces of scrap metal (including steel piles) situated at the north end of the reef.

Placement Method

The material was loaded onto a barge by a crane with a clamshell bucket. The loaded barge and a barge with the crane were transported to the reef site and the material placed by the crane with clamshell bucket. The reef site was surveyed by S.C.U.B.A. divers as well as a land survey crew to ensure the reef was located outside a nearby navigation channel and at the intended water depth.

Reef Size

The artificial reef is estimated to be 110 metres in length and an average of 26 metres wide. The maximum relief of the reef is about 2 metres. The total area or footprint of the reef is estimated to be 3120 square metres.

Monitoring

Physical and biological surveys of the artificial reef near Shaft Point in Departure Bay were undertaken in July, September, and November of 1990, in August 1992 (twice), and in June of 1993.

Survey Method

Only qualitative information was collected during the surveys conducted on July 12, 1990 and September 10, 1990.

For the survey conducted on November 5, 1990, only qualitative data was collected for cryptic fish (i.e. crevice dwelling) and algae. Algae abundance was recorded for conspicuous species on a percent coverage basis. For fish observed swimming over the reef, a variation on the stationary sampling methodology, described in Bohnsack and Bannerot (1986) for assessing coral reef fishes, was used. The stationary sampling methodology is based on censuses taken at randomly selected points on the reef by S.C.U.B.A. divers. At each sampling point, information is collected for all fish species observed over the reef within an imaginary cylinder whose dimensions of a 6 metre radius and 6 metre height were determined by the underwater visibility at the time of the survey and the distance at which a fish could be readily identified. For invertebrates, individuals were counted on the reef and in crevices within a 1 metre radius of each sampling point. Invertebrate enumeration was restricted to large conspicuous species such as seastars and crabs. For the surveys conducted on August 17 and 28, 1992 and on June 24, 1993, information was collected from transects established across the width of the reef by divers using S.C.U.B.A. Fish and invertebrate enumeration was restricted to large conspicuous species (i.e. fish, such as rockfish, greenling, lingcod, perch and large sculpins and invertebrates, such as seastars and crabs). Algae abundance was recorded also for conspicuous species but on a percent coverage basis. There was no statistical analysis of any of the survey data collected.

Fish Survey Results

Pile perch (Rhacochilus vacca), black-eyed gobies (Coryphopterus nicholsi) (observed in crevices), and striped perch (Embiotoca lateralis) were observed during all surveys. Kelp greenling (Hexagrammos decagrammus) and lingcod (Ophiodon elongatus) were observed on all surveys except the June 1993 survey. Quillback rockfish (Sebastes maliger) and kelp perch (Brachyistius frenatus) were observed on all surveys except the August 1992 and June 1993 surveys. Copper rockfish (Sebastes caurinus) were only observed on the July 1990, November 1990 and August 1992 surveys. Large schools of tubesnouts (Aulorhynchus flavidus) were only observed on the July 1990, August 1992, and June 1993 surveys. Large schools of shiner perch (Cymatogaster aggregata) were observed only on the September 1990, August 1992, and June 1993 surveys. Black rockfish (Sebastes melanops) and a large school of pacific herring Clupea harengus pallasi) were observed on the reef during the June 1993 survey.

Invertebrate Survey Results

Red rock crabs (Cancer productus), leather stars (Dermasterias imbricata), sunflower stars (Pycnopodia helianthoides), and California sea cucumbers (Parastichopus californicus) were observed during all surveys. The sunflower stars observed during the July 1990 survey were small (less than 15 cm diameter). Coonstripe shrimp (Pandalus danae) were observed on all but the September 1990 survey. The coonstripe shrimp recorded during the July 1990 survey were juveniles (less than 3 cm length) observed on loose pieces of large kelp (i.e. Laminaria saccharina and Agarum fimbriatum). Kelp crabs (Pugettia producta) were recorded on all but the November 1990 survey and were usually observed on kelp (i.e. Laminaria saccharina and Agarum fimbriatum). Acorn barnacles (Balanus glandula) were only observed on the September 1990 and August 1992 surveys. Ochre seastars (Pisaster ochraceus) were observed only on the September 1990 and June 1993 surveys. Short spined stars (Pisaster brevispinus) were observed only on the September 1990 and November 1990 surveys. Plumose anemones (Metridium senile) and unidentified nudibranchs were observed on the August 1992 and June 1993 surveys only.

Algae Survey Results

L. saccharina was observed on all but the June 1993 survey while Ulva spp. was observed on all but the July 1990 survey. Neoagardhiella spp. was observed on the September 1990, November 1990, and August 1992 surveys. A. fimbriatum was observed on only the August 1992 and June 1993 surveys. Other algae observed on the reef included Gigartina spp., Sargassum spp., as well as leafy red algaes (such as Irideae spp.) and unidentified filamentous brown algae. On the July 1990 survey, loose pieces of mature A. fimbriatum and L. saccharina were observed in reef crevices but none were attached to the reef.

Summary

In general, the surveys indicate that marine life has become well established on the artificial reef. The fish community on the reef was abundant but, due to the short age of the reef, the community may be still in a state of transition and may

not have yet reached a stable climax community. The invertebrate community has shown a steady increase in abundance and diversity since reef construction. The algal community has changed over time from one dominated by Neoagardhiella spp. to one dominated by L. saccharina and A. fimbriatum. Although the June 1993 survey showed an abundance of Sargassum spp. it appears that A. fimbriatum has and will remain the dominant species on the reef with only slight changes in other algae species.

References

Armstrong, J.W. 1993. A biological survey of an artificial reef at Newcastle Channel, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2212:21p.

JESSE ISLAND #1 - DEPARTURE BAY

Description

A small artificial reef was constructed near Jesse Island in Departure Bay in Nanaimo, B.C.

Purpose

The reef was constructed to assess the use of tires as an artificial reef material.

Construction Date

May 3, 1989.

Depth and Substrate

The reef was placed on a sand/silt substrate in about 8 metres depth L.L.W. adjacent to an eelgrass bed.

Reef Material

The artificial reef is made up of two triangular tire units made up of five tires each. The five tires were held together using bolts and nuts.

Placement Method

The two tire units were constructed on land. The units were placed on a small boat and pushed off the boat into the water by hand. Final placement of the tire units on the seabed was conducted by divers using S.C.U.B.A. The tire reef units were not anchored to the sea floor.

Reef Size

Each tire unit was approximately 1.5 metres by 1.5 metres in size for a total area (footprint) of about 5.0 square metres. The two tire units were placed approximately 1.5 metres apart.

Monitoring

Biological surveys of the tire reef near Jesse Island were undertaken on September 7, 1989 and November 10, 1989, as well as February 25, 1991.

Survey Method
Information was collected from the entire reef by divers using S.C.U.B.A. Fish enumeration was restricted to conspicuous fish species, such as rockfish and sculpins. Conspicuous marine invertebrates were also enumerated and conspicuous marine algae were recorded on the basis of percent cover and estimated frond length. There was no statistical analysis of any of the survey data collected.

Fish Survey Results
Several unidentified gobies (Family Gobiidae) and ronquils (Family Bathymasteridae) were observed during all three surveys. One juvenile kelp greenling (Hexagrammos decagrammus) was observed on the reef during the September 7, 1989 survey.

Invertebrate Survey Results
Several orange encrusting bryozoans (Membranipora spp.) and small barnacles (Balanus spp.) were observed on the reef during the September and November 1989 surveys. One rock crab (Cancer productus) was observed during the September 1989 survey. No invertebrates were observed during the February 1991 survey although some empty barnacles were observed.

Algae Survey Results
Neoagardhiella spp. and Sargassum spp. were observed during all three surveys. Sargassum spp. remained small (less than 2 cm length) while the frond length of Neoagardhiella spp. increased from 2 cm to 20 cm to 25 cm over the three surveys. Ulva spp. was only observed during the September and November 1989 surveys and increased from 3 cm to 15 cm between the two surveys. One Agarum spp. individual of about 60 cm length was observed on the reef during the February 1991 survey.

Summary
During the period surveys were conducted, marine flora and fauna have continued to establish on the tire reef. It should be noted that a cinder block reef (see Jesse Island #2) was constructed adjacent to the tire reef. Reef assessments indicated that the presence and abundance of marine life (fish, invertebrates, and algae) on both the tire reef and the cinder block reef (Jesse Island #2) were very similar. The one exception is for algae which during the September 1989 and November 1989 surveys Laminaria saccharina was observed on the cinder block reef but not on the tire reef.

Regardless of the biological productivity of the Jesse Island #1 tire reef, tires are not recommended for use as artificial reefs. While the tire reefs appeared stable, surveys were conducted only over a several month period after reef construction. Studies have indicated that one of the major problems regarding the use of used tires for artificial reefs is their instability on the sea floor, due to their buoyancy, if not adequately anchored or weighted. Also cables, bolts, etc. used to hold the tires together may also corrode in a relatively short period of

time, releasing the tires which then could easily be moved by currents, tides and surface wave action. Some studies have also identified a potential concern regarding the leaching of contaminants (e.g. metals) from used tires but none conclusively document the release of contaminants or related effects on marine life.

References

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Naito, B.G. 1989. Memoranda to file dated March 16, 1989, May 4, 1989, September 7, 1989, and November 10, 1989.

JESSE ISLAND #2 - DEPARTURE BAY

Description

A small artificial reef was constructed near Jesse Island in Departure Bay in Nanaimo, B.C.

Purpose

The reef was constructed to assess the use of cinder blocks as an artificial reef material.

Construction Date

January 9, 1989.

Depth and Substrate

The reef was placed on a sand/silt substrate in about 8 metres depth L.L.W.

Reef Material

The artificial reef is made up of approximately 54 cinder blocks.

Placement Method

The cinder blocks were placed on a small boat and pushed off the boat into the water by hand. S.C.U.B.A. divers then arranged each cinder block from the pile into a branching pattern on the sea bottom. The reef was located on a slope so rebar was used to keep the cinder blocks and reef in place.

Reef Size

The reef is approximately 4.5 metres long and averages 1.5 metres wide with a vertical relief of less than 1 metre.

Monitoring

Biological surveys of the cinder block reef near Jesse Island were undertaken in March 16, 1989, May 4, 1989, September 7, 1989, and November 10, 1989, as well as February 25, 1991.

Survey Method

Information was collected from the entire reef by divers using S.C.U.B.A. Fish enumeration was restricted to conspicuous fish species, such as rockfish and sculpins. Conspicuous marine invertebrates were also enumerated and conspicuous marine algae were recorded on the basis of percent cover and estimated frond length. There was no statistical analysis of any of the survey data collected.

Fish Survey Results

Several unidentified gobies (Family Gobiidae) and ronquils (Family Bathymasteridae) were observed on the reef during the May 1989, September 1989, November 1989, and February 1991 surveys. Only one unidentified juvenile flatfish was observed during the March 1989 survey. Four pile perch (Rhacochilus vacca) and one juvenile kelp greenling (Hexagrammos decagrammus) were observed on the reef during the September 1989 survey.

Invertebrate Survey Results

One or two red rock crabs (Cancer productus) was observed during each of the March 1989, September 1989, and November 1989 surveys. One or two seastars were observed during each of the March 1989, May 1989, September 1989, and February 1991 1989 surveys. The seastars observed during the March 1989 and May 1989 surveys were unidentified juveniles while the seastars observed during the September 1989 survey were mottled star (Evasterias troschellii) adults. During the February 1991 survey one morning sun star (Solaster dawsoni) individual was observed. Small barnacles (Balanus spp.) were observed on the reef during all surveys except the March 1989 survey, although during the November 1989 and February 1991 surveys most of the barnacles appeared empty or dead. Several orange encrusting bryozoans (Membranipora spp.) were observed during the September 1989 and February 1991 surveys. One coonstripe shrimp (Pandalus danae) was observed during the May 1989 survey while a plumose anemone (Metridium senile) and a decorator crab (Oregonia gracilis) individual were observed during the February 1991 survey.

Algae Survey Results

A high percent coverage of long thin-stranded filamentous algae was evident on the reef during the March 1989 and May 1989 surveys. Laminaria saccharina was observed during the May 1989, September 1989, and November 1989 surveys. L. saccharina individuals were about 20 cm long during the May 1989 survey and about 50 cm to 100 cm long during the latter surveys. Neoagardhiella spp. was observed during the September 1989, November 1989, and February 191 surveys. The frond length of Neoagardhiella spp. increased from 3 cm to 20 cm to 25 cm over the three surveys. Ulva spp. was only observed during the September and November 1989 surveys and increased from 3 cm to 15 cm between the two surveys. Small individuals of Sargassum spp. (less than 2 cm length) were observed during the November 1989 and February 1991 surveys. Unidentified leafy red algae (less 15 cm long) were observed on the reef during the September 1989 and February 1991 survey.

Summary
During the period surveys were conducted, marine flora and fauna have established on the reef. It should be noted that a tire reef (see Jesse Island #1) was constructed adjacent to the cinder block reef. It should be noted that the presence and abundance of marine life (fish, invertebrates, and algae) on both the tire reef (Jesse Island #1) and the cinder block reef (Jesse Island #2) were very similar. The one exception is for algae which during the September 1989 and November 1989 surveys L. saccharina was observed on the cinder block reef but not on the tire reef.

References

Naito, B.G. 1991b. Memorandum to file. February 25, 1991.

Naito, B.G. 1989. Memoranda to file dated March 16, 1989, May 4, 1989, September 7, 1989, and November 10, 1989.

FRENCH CREEK

Description
Two rock groins were built as projections off the foreshore of French Creek, B.C. to act as artificial reefs.

Purpose
The reefs were created to compensate for the loss of foreshore habitat as a result of the placement of fill.

Construction Date
Spring 1984.

Depth and Substrate
The rock groins were placed on a sand substrate.
The groins extend from above the high water mark to about 9 m below local low water.

Reef Material
The material used was rock rip rap ranging from 1 to 2 m diameter.

Placement Method
The reef material was transported to the site by truck. The material was endhauled and moved into place by a excavator working at low tide.

Reef Size
The reef is approximately 90 metres long and 25 metres wide with a maximum relief of approximately 6 metres. The total area (footprint) of the reef is estimated to be 2200 square metres.

Monitoring

Physical and biological surveys of the artificial reef at French Creek were undertaken in November 5, 1987, November 17, 1987 (fish enumeration only), March 20, 1988, December 8, 1988, June 5, 1991, and September 12, 1991 (fish enumeration only). The survey dates were chosen to attempt to determine seasonal variations in the biological characteristics of the reef. One of the November 1987 biological surveys was conducted at night to assess diel changes in fish use of the reef in November 1987.

Survey Method

Information was collected from transects established across the width of the reef by divers using S.C.U.B.A. Fish and invertebrate enumeration was restricted to large conspicuous species (i.e. fish, such as rockfish, greenlings, lingcod, perch and large sculpins and invertebrates, such as seastars and crabs. Individual fish length and total fish biomass estimates were also made. Algae abundance was recorded also for conspicuous species but on a percent coverage basis. There was no statistical analysis of any of the survey data collected.

Fish Survey Results

Diel - November 1987

The total fish population and total fish biomass on the reef was estimated to be higher at night than during the day. In most cases, the number and biomass estimated for each species of fish enumerated was also higher at night. The exceptions were striped perch (Embiotoca lateralis), which decreased in abundance at night and increased in biomass during the day, and juvenile kelp greenlings (Hexagrammos decagrammus), painted greenlings (Oxylebius pictus), shiner perch (Cymatogaster aggregata), and juvenile lingcod (Ophiodon elongatus), which were observed during the day but not at night. Those fish species, which showed an estimated increase in biomass at night, were not always present in correspondingly higher numbers at night. For juvenile copper rockfish (Sebastes caurinus), striped perch (E. lateralis), and pile perch (Rhacochilus vacca), the increase in biomass from day to night was many times greater than the increase in numbers of individuals counted during the same time period. This suggests that for the three species observed, the fish were larger at night than during the day.

Some species of fish on the reef exhibited different behaviour at night compared with the day. During the day rockfish were almost always observed in crevices on the reef, whereas, at night they were observed both hiding in crevices and swimming over the reef in small schools. Striped perch (E. lateralis) and pile perch (R. vacca), were observed schooling over the reef during the day while at night these two species were seen both hiding in crevices and swimming over the reef. Striped perch (E. lateralis) were found in large schools during the day and as solitary individuals or in very small schools at night.

Seasonal

Total fish numbers on the French Creek artificial reef were estimated to be

highest in the winter and lowest during the summer. The percentage of the total number of fish on the reef estimated to be benthic (found in crevices) was lowest in the winter and highest in the summer while the percentage estimated to be neritic (swimming over the reef) was highest in the winter and lowest in the summer. Of the total benthic fish on the reef, the percentage of rockfish was highest in the summer and lowest in the winter and spring while the percentage of greenlings (except lingcod (O. elongatus)) was highest in the fall and lowest in the winter, spring, and summer. Of the total neritic fish on the reef, the percentage of rockfish (Sebastes spp.) and lingcod (O. elongatus) were highest in the summer and lowest in the winter while the percentage of striped perch was lowest in the summer and highest in the winter and spring and the percentage of pile perch (E. lateralis) was highest in the fall and lowest in the winter.

Invertebrate Survey Results

A detailed description of seasonal changes in the pattern and relative abundance of macroinvertebrates was beyond the scope of the report. However, in general, seastars were estimated to be the most abundant macroinvertebrate on the reef during the surveys. Seastars observed included ochre stars (Pisaster ochraceus), leather stars (Dermasterias imbricata), short spined stars (Pisaster brevispinus), morning sun stars (Solaster dawsoni), Other abundant macroinvertebrates observed included northern kelp crabs (Pugettia producta), red rock crabs (Cancer productus), painted tealia anemones (Tealia crassicornis), California sea cucumbers (Parastichopus californicus), sea lemon nudibranchs (Archidoris montereyensis), purple sea urchins (Strongiyocentrotus purpuratus).

Algae Survey Results

A detailed description of seasonal changes in the pattern and relative abundance of macroalgae was beyond the scope of the report. However, red algae represented the most percentage cover on the reef during the surveys. Red algae species included Corallina spp. (including Corallina vancouveriensis), Iridaea spp., Laurencia spectabillis, Mastocarpus spp., Neoagardhiella baileyi, Porphyra perforata, Callophyllis spp., Polyneura spp., Microcladia spp., and Rhodymenia pertusa. Brown algae (in the form of kelps) were also well represented on the reef and included Costaria costata and Laminaria saccharina. The green algae Ulva spp. and the brown algae Fucus spp. were also observed but only in the intertidal zone.

Summary

In general, the first survey conducted in November 1987 indicated that marine life has become well established on the artificial reef. The fish community on the reef was abundant and represents individuals from all size classes. The large number of juvenile fish indicates that the reef may be used as a nursery area. The invertebrate and algal communities are also abundant. Subsequent surveys in March 1988, December 1988, June 1991, and September 1991 show that since construction marine life continued to be well established on the reef.

References
Naito, B.G. 1991a. A biological survey of an artificial reef at French Creek, British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2100:48p.

CAMPBELL RIVER

Description
Two separate artificial reefs were constructed near the fishing pier in Campbell River, B.C.

Purpose
The reef was constructed to compensate for the loss of fish habitat due to the upland expansion of the Campbell River Small Craft Harbour.

Construction Date
Spring 1986.

Depth and Substrate
The reef was placed on a sand substrate in about 9 metres depth L.L.W.

Reef Material
The artificial reef is made up of large rock rip rap ranging from 0.5 to 1.5 metres diameter.

Placement Method
The material was loaded onto a barge by a crane with a clamshell bucket. The loaded barge and a barge with the crane were transported to the reef site and the material placed by the crane with clamshell bucket. The reef is located just beyond casting distance from the Campbell River Sportfishing Pier.

Reef Size
The two separate reefs are essentially one long reef with a break in the centre. The two reefs together are about 120 metres in length and both average about 11 metres wide with a vertical relief of about 2.5 metres. The total area or footprint of both reefs is about 1800 square metres.

Monitoring
A physical and biological survey of the Campbell River artificial reef was conducted on March 27, 1988.

Survey Method
Survey efforts were conducted by two S.C.U.B.A. divers using a boat operated by a boat tender. The two S.C.U.B.A. divers qualitatively observed the biological characteristics of the artificial reef by recording the presence of conspicuous fish, invertebrates, and algae. Only qualitative observations were made as the time

underwater was very limited due to the short duration of the slack tide period and the occurrence of a very fast current during tide changes.

Fish Survey Results

Fish observed on the reef included numerous copper rockfish (Sebastes caurinus), lingcod (Ophiodon elongatus), kelp greenlings (Hexagrammos, decagrammus), red irish lords (Hemilepidotus hemilepidotus), and cabezons (Scorpaenichthys marmoratus).

Invertebrate Survey Results

Conspicuous invertebrates observed on the reef included sunflower stars (Pycnopodia helianthoides), morning sun stars (Solaster dawsoni), mottled stars (Evasterias troschelii), and purple sea urchins (Strongylocentrotus purpuratus). Two pacific octopus (Octopus dolfleini) were also observed on the reef.

Algae Survey Results

The majority of the conspicuous algae species on the reef included brown algae, such as Cymathere triplicata, Laminaria saccharina, Pleurophycus gardneri, and juvenile Nereocystis luetkeana. Numerous types of leafy red algae were also observed, such as Iridaea spp.

Summary

Marina flora and fauna on the Campbell River artificial reef has become well established. The establishment of marine life on the reef may have been enhanced by the strong tidal currents at the reef site and/or the location of the reef in or in the vicinity of an area restricted from harvest by S.C.U.B.A. divers and set aside for the preservation of underwater marine life.

It should be noted that although strong tidal currents may promote biological productivity on reefs, strong currents have been identified as contributing to reef damage or loss resulting from scattering of and/or sedimentation over reef materials. In the case of the Campbell River artificial reef, the reef was designed to withstand the strong tidal currents. However, there is evidence of a build up of sand and wood debris at the base of the reef but further study is required to determine if the buildup has stabilized or will continue.

References

Naito, B.G. 1988a. An assessment of the Campbell River artificial reef - March 27, 1988. Unpubl. report prepared for Public Works Canada. 10pp.

TZARTUS ISLAND - BARKLEY SOUND

Description

An artificial reef was placed near Tzartus Island in Barkley Sound, B.C.

Purpose
The reefs were created to act as compensation for habitat impacts as a result of the installation of a log dump and creation of a log storage area.

Construction Date
Spring 1993

Depth and Substrate
The reef was placed on a silt/sand substrate at approximately 10 metres depth L.L.W.

Reef Material
Rip Rap

Placement Method
Unknown

Reef Size
Unknown

Monitoring
A qualitative biological survey was conducted in 1997.

Survey Method
The biological survey was conducted by S.C.U.B.A. divers.

Survey Results
The survey indicated that the reef has become established with a variety of invertebrate, fish and algal species.

BAMFIELD - BARKLEY SOUND

Description
Ten separate artificial reefs were placed in Ross Islet near the Bamfield Marine Station in Barkley Sound, B.C.

Purpose
The reef was created as an experiment to assess the development of nearshore reef fish assemblages on artificial reefs.

Construction Date
Four of the reefs were constructed in February 1978 and six were constructed in August 1978.

Depth and Substrate
The reefs were placed in 8 to 10 metres depth on a sand substrate. Five reefs

were located at 10 metres distance from a rock rubble slope, one reef was located at 7 metres from a rock rubble slope, and four reefs were located in direct contact with the rock rubble slope.

Reef Material

The reef material was composed of cinder blocks of three different sizes. The different sized blocks had four different sizes of internal openings: small blocks - 9.3 cm x 3.6 cm, medium blocks - 14 cm x 8 cm, and large blocks - 18 cm x 21 cm and 6 cm x 18 cm.

Placement Method

The cinder blocks were placed using S.C.U.B.A. divers.

Reef Size

Each of the ten artificial reefs were 2.4 m long by 0.6 m wide and 0.9 m height. Each reef was a terraced structure with three levels of decreasing width from bottom to top.

Monitoring

Quantitative assessments of fish and qualitative assessments of invertebrates and algae on the reefs were conducted at 12 to 17 day intervals between February 1978 and August 1979.

Survey Method

Biological assessments were conducted using S.C.U.B.A. Each reef was small enough to count fish on the outside and in the crevices of each reef. Two divers approached opposite sides of each reef and counted all fish on the outside of the reef. The two divers then switched sides and counted the fish in holes inside each reef.

Fish Survey Results

Thirty species of fish were recorded on the artificial reefs. The most common fish species from highest to lowest abundance were black rockfish (Sebastes melanops), blackeye gobies (Coryphopterus nicholsi), quillback rockfish (Sebastes maliger), copper rockfish (Sebastes caurinus), kelp greenling (Hexagrammos decagrammus), canary rockfish (Sebastes pinniger), and longfin sculpin (Jordania zonope). Most of the fish species observed on the adjacent rock rubble slope were also observed on the artificial reefs. The artificial reefs that were in direct contact to the rock rubble slope colonized with fish faster than the reefs located offshore of the rock rubble slope. Fish numbers were lowest in the winter but increased during the summer and early fall, especially, for mobile species such as Hexagrammidae, Scorpaenidae, and Embiotocidae). Schools of rockfish (S. melanops and S. pinniger) were only observed from June to September with individuals of these species observed all year. Of the fish species on the reefs, all were observed as juveniles or adults except for rockfish (Sebastes spp.) which were only observed as juveniles.

Invertebrate and Algae Survey Results
The artificial reefs were quickly colonized by invertebrates (such as hydroids (Obelia spp.), serpulid worms, encrusting corralline algae, and red sea urchins (Strongylocentrotus franciscanus) and algae (such as N. luetkeana, C. Costata, Laminaria spp., Ulva spp., and Porphyra spp.).

Summary
The biological assessment indicated that marine life has become well established on the artificial reefs. The fish community on the reefs was abundant and, except for rockfish (Sebastes spp.), was represented by both juveniles and adults. The invertebrate and algal communities are also abundant.

References
Gascon, D. and R.A. Miller. 1981. Colonization by nearshore fishes on small artificial reefs in Barkley Sound, British Columbia. Can. J. Zool. 59: 1635-1646.

KUNECHIN POINT - SECHELT INLET

Description
An old ship was sunk near Sechelt, B.C. to act as an artificial reef.

Purpose
The reef was created as a recreational S.C.U.B.A. diving attraction.

Construction Date
The vessel was sunk on December 5, 1992 by the Artificial Reef Society of B.C.

Depth and Substrate
The vessel was sunk in approximately 27 m depth. The substrate at the site is not known.

Reef Material
The reef material was composed of an old ship (the H.M.C.S. Chaudiere).

Placement Method
The vessel was floated to the reef site and explosive charges detonated in strategic locations on the ship to allow the ship to fill with water and sink.
All floatables, fuel oil, hydraulic fluids, lubricants and other petroleum based products were removed from vessels prior to sinking.

Reef Size
The ship represented a quantity of 2,370 tonnes.

Monitoring
Unknown

References
Kim, K. and D.L. Sullivan. 1993. Ocean disposal activities summary from 1987 to 1992 for Pacific and Yukon Region. Department of Environment, Conservation and Protection, Environmental Protection, Pacific and Yukon Region. Regional Program Report 93-01. 173pp.

PATRICIA BAY

Description
A small floating reef was located near the Institute of Ocean Sciences in Patricia Bay, B.C.

Purpose
The reef was created as an experiment.

Construction Date
1988

Depth and Substrate
The floating reef was located on the water surface over a silt substrate.

Reef Material
The reef material was composed of 3 inch diameter PVC pipe glued together into a cubic shape.

Placement Method
The reef was constructed on land and floated to the reef site. The reef in anchored with a number of cinder blocks.

Reef Size
The floating reef was approximately 1 metres by 1 metre in size.

Monitoring
A qualitative biological survey was conducted in 1990.

Survey Method
The biological survey was conducted by two S.C.U.B.A. divers.

Survey Results
The survey indicated that the reef was densely covered with green sea urchins (Strongylocentrotus droebachiensis) only. Previous surveys indicated no use by fish or colonization by macroinvertebrate or macroalgae species. However, a qualitative survey of a constructed rock breakwater adjacent to the floating has shown that the rock berm has been colonized by macroalgae and macroinvertebrates.

Summary
The floating reef has not been well colonized by macroalgae or macroinvertebrates. Given that adjacent rock areas have become well colonized, it may be that the PVC pipe material used for the reef may not be suitable for the establishment of a diverse floral or faunal community.

References
Naito, B.G. 2000. Personal Communication.

PRINCESS MARGARET PROVINCIAL PARK

Description
An old ship was sunk to act as an artificial reef at Portland Island located north of the Saanich Peninsula, B.C.

Purpose
The reef was created as a recreational S.C.U.B.A. diving attraction.

Construction Date
The vessel was sunk on August 10, 1991 by the Artificial Reef Society of B.C.

Depth and Substrate
The vessel was sunk in approximately 22.5 m depth.
The substrate type was sand.

Reef Material
The reef material was composed of an old ship (G.B. Church).

Placement Method
The vessel was floated to the reef site and explosive charges detonated in strategic locations on the ship to allow the ship to fill with water and sink.
All floatables, fuel oil, hydraulic fluids, lubricants and other petroleum based products were removed from vessels prior to sinking.

Reef Size
The ship was approximately 53 metres long and represented a quantity of approximately 530 tonnes.

Monitoring
Qualitative biological surveys were conducted in 1993 and 1994.

Survey Method
The biological survey was conducted by S.C.U.B.A. divers.

Survey Results

The survey indicated that the outer hull of the reef has become established with a variety of invertebrate, fish and algal species.

References

Ellis, D. 1993. HMCS Chaudiere Monitoring Survey Results, April 1993. Environment Canada Regional Data Report 93-01.

Kim, K. 1994. HMCS Chaudiere Monitoring Survey Results, February 1994. Environment Canada Regional Data Report 94-01.

Kim, K. and D.L. Sullivan. 1993. Ocean disposal activities summary from 1987 to 1992 for Pacific and Yukon Region. Department of Environment, Conservation and Protection, Environmental Protection, Pacific and Yukon Region. Regional Program Report 93-01. 173pp.

Subsea Enterprises Inc. 1994. A biological assessment of the "G.B. Church" artificial reef at Princess Margaret Provincial Park. Report prepared for BC Ministry of Environment, Lands and Parks.

ROBERTS BANK

Description

Two distinct reefs (Reef A and Reef B) were placed immediately inside (northeast) of the pile supported wharf of the Coal Terminal at the Roberts Bank Port Development near Vancouver, B.C.

Purpose

The reefs were created as part of the Habitat Compensation Program for the expansion of the Roberts Bank Port Development.

Construction Date

1983

Depth and Substrate

Reef A was placed at about 10 metres depth while Reef B was placed between 10 and 15 metres depth. Both reefs were placed on a silt substrate.

Reef Material

Both reefs were composed of broken concrete pipe, each approximately 600 mm diameter and measuring about 2.5 metres length.

Placement Method

Material was placed from a barge.

Reef Size

The length of each reef was approximately 60 metres. The maximum relief of

Reef A was approximately three pipe diameters high while Reef B was composed of scattered pieces of pipe (1 metre separation minimum and one pipe layer of relief) partially if not all buried in sand substrate. October 26, 1992 - generally positioned flat on the sea bottom in groupings of 3 to 4 pieces.

Monitoring

Physical and biological surveys of the artificial reefs were undertaken on December 10, 11, & 12, 1984, July 19, 1985, October 25, 1985, and October 26, 1992. The data from the July 19, 1985 survey was not readily available.

Survey Method

During the December 1984 survey, information was collected from transects established across the width of the reef by divers using S.C.U.B.A. Fish and invertebrate enumeration was restricted to conspicuous species. Algae abundance was recorded along transects for conspicuous species on a percent coverage basis. Biological information was also collected from adjacent breakwaters and from the sand seafloor but the data collected was inconclusive with respect to comparisons to the reefs. There was no statistical analysis of any of the December 1984 survey data collected. Only qualitative biological information was collected from the October 25, 1985 and October 26, 1992 surveys.

Fish Survey Results

During the December 1984 survey, one lingcod (Ophiodon elongatus) was observed on Reef A in a survey area of approximately 360 m^2. No fish were observed on Reef B in a similarly sized survey area. Fish observed on the reefs during the October 25, 1985 and October 26, 1992 surveys included lingcod (O. elongatus), copper rockfish (Sebastes caurinus), kelp greenling (Hexagrammos decagrammus), striped perch (Embiotoca lateralis), and unidentified sculpins. Bay gobies (Lepidogobius lepidus) were observed during the October 25, 1985 survey only but this species may not have been recorded during the October 26, 1992 survey. Pile perch (Rhacochilus vacca) and quillback rockfish (Sebastes maliger) were only observed during the October 26, 1992 survey. The December 1984 survey indicated that fish population of reefs was low compared to other reefs in the Pacific Northwest likely because of pipe diameter too large to provide fish shelter and that the pipe was placed in a manner that did not create suitable voids for fish shelter (especially Reef B). Also during the October 25, 1985 survey it was suggested that there was a drastic reduction in aquatic life on Reef B compared to Reef A likely due to the limited amount of crevice and sheltered areas created by the arrangement of the pipe material on Reef B.

Invertebrate Survey Results

During the December 1984 survey, 2-3 dungeness crabs (Cancer magister) were observed on the reef and 7-8 orange sea pens (Ptilosarcus gurneyi) were observed on the sand substrate between the reefs in a total survey area of approximately 120 square metres per reef. The most common invertebrates observed on the reefs during the October 25, 1985 survey included mostly juvenile (< 5 cm high) plumose anemones (Metridium senile), numerous ochre

seastars (Pisaster ochraceus), jingle shells (Pododesmus cepio), bryozoans (Bugula spp.), barnacles (Balanus spp.), red rock crabs (Cancer productus), dungeness crabs (C. magister), coonstripe shrimp (Pandalus danae), and ascidians. Orange sea pens (P. gurneyi), and various nudibranchs were observed on the sand substrate associated with Reef B. The most common invertebrates observed during the October 26, 1992 survey included the hydroid coral Abietinaria spp., the ascidian Boltenia villosa, transparent sea squirts (Corella willmeriana), the nudibranch Dirona albolineate, mottled seastars (Evasterias troschelli), plumose anemones (M. senile), coonstripe shrimp (P. danae), short spined star (Pisaster brevispinus), ochre seastars (P. ochraceus), orange seapens (P. gurneyi), sunflower seastars (Pycnopodia helianthoides), and painted anemones (Urticina crassicorns). Plumose anemones (M. senile) were the most abundant during the October 26, 1992 survey.

Algae Survey Results

No conspicuous algae was observed on either reef during the December 1984 survey. During the October 25, 1985 survey, only encrusting coralline algae was observed on the reef. Bull kelp (N. luetkeana) and various low growing red algaes were observed on the reefs during the October 26, 1992 survey. The absence of vegetation on reefs in the December 1984 survey was explained by low light penetration due to the depth of reef and high turbidity of surrounding waters.

Summary

The low abundance of algae on the artificial reefs may be limited by low light conditions due to the depth of the reefs and/or turbidity associated with the nearby Fraser River. The author notes that recent surveys of adjacent rock areas in shallower water have been observed to be covered with dense coverage of foliose red algae and kelps. Also differences in fish abundance between the two reefs may be due to one of the reefs having voids too large for fish shelter.

References

B.C. Rail. 1985. Letter to the Department of Fisheries and Oceans dated October 30, 1985 regarding December 10, 11, & 12, 1984 and July 19, 1985 Roberts Bank Reef surveys.

Department of Fisheries and Oceans. 1985. Internal memorandum from M. Adams to O. Langer and K. Conlin dated November 14, 1995 regarding October 25, 1985 Roberts Bank Reef survey.

Roberts Bank Environmental Review Committee. 1996. Final report of the Roberts Bank Environmental Review Committee, 1996. 31pp.

Vancouver Port Corporation. 1992. Letter from D.J. Desjardin of VPC to B. Naito of DFO dated January 25, 1993 plus attached video entitled "Video inspection of artificial reef at Roberts Bank Terminal, October 26, 1992" prepared for VPC by Subsea Enterprises Inc.

BERRY POINT - BURRARD INLET

Description
Six distinct artificial reef clusters were placed off shore near Berry Point in Burrard Inlet in Burnaby, B.C.

Purpose
The reefs were created to act as compensation for habitat impacts as a result of sidecast dredging.

Construction Date
August 29, 1992

Depth and Substrate
The reef clusters were placed on a shell and sand substrate.
Three clusters were placed just seaward of the minus 10.0 foot (chart datum) depth contour and the remaining three clusters were placed just shoreward of the minus 15.0 foot (chart datum) depth contour.

Reef Material
Material used included approximately 1750 tonnes of 8 to 18 inch quarry rock (granite) and 300 tonnes of precast/36 inch diameter core/round pilings (24 sections with a length range of 30 to 40 feet).

Placement Method
Material was placed using barge and crane with a clamshell bucket.
Cluster creation entailed the initial placement of 4 pilings in a rectangular configuration. Following placement of pilings as a base for each cluster, rock was deposited at the centre of the rectangular configuration. The placement of rock proceeded until the apex of each cluster was at approximately 0.0 feet chart datum.

Reef Size
The reef clusters were rectangular with sides measuring approximately 30 to 40 feet with a maximum relief of approximately 15 feet.

Monitoring
A qualitative survey of the reef was conducted on September 6, 1992 (8 days after reef construction).

Survey Method
During the September 6, 1992 survey, information was collected by divers using S.C.U.B.A. Fish and invertebrate enumeration was restricted to conspicuous species. Algae abundance was recorded on a percent coverage basis.

Fish Survey Results
Fish observed during the survey from highest to lowest abundance included shiner perch (Cymatogaster aggregata), striped perch (Embiotoca lateralis), sculpins (Cottidae spp.) and kelp greenling (Hexagrammos decagrammus).

Invertebrate Survey Results
Invertebrates observed during the survey included coonstripe shrimp (Pandalus danae), california sea cucumbers (Parastichopus californicus), kelp crab (Pugettia producta), six-rayed seastars (Leptasterias hexactis), a red rock crab (Cancer productus), a mottled seastar (Evasterias troschelli), a leather seastar (Dermasterias imbricata), as well as an unidentified snail and nudibranchs.

Algae Survey Results
Only diatomaceous filaments (Bacillariophyta spp.) at a maximum of 20% areal cover were observed on the reef.

Summary
While fish, invertebrates and algae were observed during the monitoring that was conducted only eight days after construction, further long-term monitoring is required to assess the establishment of flora and fauna on the reef.

References
ECL Envirowest Consultants Ltd. 1992. Letter to the Department of Fisheries and Oceans dated September 21, 1992 regarding Chevron Burnaby Refinery – Placement of Artificial Reef Clusters.

ECL Envirowest Consultants Ltd. 1992. Site Selection For The Placement Of Artificial Reef Clusters: A Survey of Aquatic Habitats At The Chevron Refinery Docking Facility, Burrard Inlet, Burnaby, B.C. July 1992. Prepared For Fraser River Pile & Dredge Ltd. 10pp plus appendices.

DUNDARAVE / AMBLESIDE - BURRARD INLET

Description
An artificial reef was placed off shore of the areas of Dundarave and Ambleside in West Vancouver, B.C. in Burrard Inlet.

Purpose
The reef was created to act as compensation for habitat impacts as a result of the placement of fill.

Construction Date
October 1989.

Depth and Substrate
The reef was placed on a sand/shell substrate at less than 10 metres depth local

low water. The exact depth of the reef is not known.

Reef Material
The material used for the reef included an unspecified amount of rip rap.

Placement Method
The artificial reef was placed immediately offshore of an existing kelp bed located parallel to the shore. Prior to reef placement S.C.U.B.A. divers marked the seaward boundary of the existing kelp bed with buoys. The rip rap was placed seaward of the buoy to ensure that the reef would not impact the existing kelp bed and to attempt to place the rip rap at the same depth as the existing kelp bed. The rip rap material was loaded onto a barge and placed into the water by a crane with clamshell bucket located on the barge.

Reef Size
A survey conducted October 17, 1989 immediately after reef placement indicated that the artificial reef consists of two rip rap areas separated by a small gaps. The foot print of one area is about 900 feet by 40 feet while the foot print of the adjacent rip rap area is 900 feet by 60 feet.

Monitoring
No physical or biological monitoring has been conducted since the reef was constructed.

References
Hay & Company Consultants Inc. 1989. Letter to the Department of Fisheries and Oceans dated November 6, 1989 regarding the October 12, 1989 survey conducted prior to reef placement and the October 17, 1989 survey conducted immediately after reef placement.

PORTEAU COVE - HOWE SOUND

Description
Artificial reefs were placed in Porteau Cove in Howe Sound, B.C.

Purpose
The reefs were constructed for a recreational S.C.U.B.A. diving attraction.

Construction Date
The reef was first built in 1972 with further additions made in the following years up to 1992. Specifically, in 1972, automobile tires were placed, in 1980, scrap concrete and two old vessels ("Fort Langley" and "Cape Spruce") were sunk by B.C. Lands and Parks and in 1985, another vessel ("Nakaya") was sunk by B.C. Lands and Parks. In 1990, scrap steel from the B.C. Ferry Terminal at Horseshoe Bay was placed. A further vessel ("Centennial III") was sunk in December 1991 and another vessel the "Grant Hull" (G.N. Transporter) was

sunk in March 1992.

Depth and Substrate

It is not known at what depth the tires or strap steel were placed. However, the scrap concrete and vessels sunk in 1980 and 1985 are in approximately 9 m depth and the vessels "Centennial" and "Grant Hull" were placed in approximately 20 m depth. The substrate type at the reef site is sand/silt.

Reef Material

As noted above, the reef is composed of tires, scrap concrete, scrap steel, and several old ships. The vessels "Fort Langley", "Cape Spruce" and "Nakaya" were wooden. It is not known what type of vessels the "Centennial III" and "Grant Hull" were but they are thought to have been steel.

Placement Method

It is not known how the tire chains were placed. For the vessels, all floatables, fuel oil, hydraulic fluids, lubricants and other petroleum based products were removed prior to sinking. The scrap steel was lowered into place using a crane on a barge.

Reef Size

Eleven tire chains (formed from between 40 and 50 individual tires joined together) were placed for a total of about 500 to 600 tires. A total of 63.5 tonnes of scrap concrete was placed. It is not known how much scrap steel was placed. With regard to the vessels, the "Fort Langley" was 137 tonnes, the vessel "Nakaya" was 260 tonnes, the vessel "Centennial III" was 15 tonnes and the vessel "Grant Hull" (G.N. Transporter) was 144 tonnes. The size of the "Cape Spruce" is not known.

Monitoring

Monitoring of the artificial reef at Porteau Cove was conducted in late 1989 (Adams and Whyte, 1990). The highest diversity of marine life was associated with the scrap concrete. Conspicuous invertebrates included coonstripe shrimp ((Pandalus danae), plumose anemones (Metridium senile), california sea cucumbers (Parastichopus californicus), pacific octopus (Octopus dolfleini), and sea stars. Abundant fish species included tube-snouts (Aulorynchus flavidus), striped perch (Embiotoca lateralis), pile perch (Rhacochilus vacca), shiner perch (Cymatogaster aggregata), lingcod (Ophiodon elongatus), copper rockfish (Sebastes caurinus), and black eye gobies (Coryphopterus nicholsi). Shallow portions of the scrap concrete appeared to support less species than deeper portions, possibly due to the presence of fresh water (lower salinity) in the upper water column at the site. Sessile marine life was not very abundant on the tires or on the wooden vessels, probably due to the material type. However, mobile invertebrates and fish were observed to be abundant in the crevice spaces of the tires and wood vessels. It should be noted that at the time of the survey the wooden "Nakaya" was heavily deteriorated while the wood vessels "Fort Langley" and "Cape Spruce" have disintegrated. It is not known in any monitoring has been conducted of the materials placed at Porteau Cove after

1989 (i.e. the scrap steel and vessels "Centennial III" and "Grant Hull").

Summary
Marina flora and fauna on the artificial reefs at Porteau Cove have become well established. However, variances in the abundance or diversity of marine life were observed between some of the reefs. For example, sessile marine life was not very abundant on the tire reef and wooden vessels likely due to differences in reef material. Also less species were supported by shallow portions compared to deeper portions of the scrap concrete reef likely due to the influence of freshwater in the upper portions of the water column.

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DISCUSSION

This report has summarized physical and biological assessments of artificial reefs in southern British Columbia. Prior to 1994, a total of fifteen artificial reefs were documented on the southern British Columbia coast. Seven of the reefs were built as compensation for fish habitat impacts associated with various marine nearshore developments while five were experimental and three were built as recreational S.C.U.B.A. diving attractions. Most of the reefs were constructed between five to fifteen metres depth (L.L.W.) although one reef was floating and three reefs were placed in over twenty metres depth (L.L.W.). Reef placement was usually onto a silt or sand and shell substrate. The type of reef material used varied with four constructed of rock rip rap and the remaining reefs made of broken concrete (three), derelict ships (two), cinder blocks (two), tires (one), and PVC pipe (one) or a combination of rock rip rap and broken concrete (one) or broken concrete, derelict ships and scrap steel (one). The size of each reef also varied with a footprint ranging from 2.5 to 9500 square metres in size and a vertical relief ranging from less than one to six metres. The biological monitoring of the artificial reefs was usually limited to qualitative rather than statistically valid quantitative data primarily due to budget and manpower constraints. Accordingly, detailed comparisons of the marine flora and fauna on

reefs based on variations in physical design characteristics (reef material, reef water depth, reef relief, location, etc.) was not possible from the information collected. However, based on the qualitative information collected, almost all of the artificial reefs were successfully colonized by a variety of marine flora and fauna. The limited success in the colonization by marine flora and fauna on a few of the artificial reefs was likely due to the type of reef material used (i.e. PVC pipe at Patricia Bay) and to reef location (i.e. near an estuary at Nanaimo Harbour). It can be generalized that marine flora and fauna appeared to be more diverse on artificial reefs located in clear open water as opposed to reefs located near estuaries (e.g. Nanaimo River estuary) where water can be turbid during periods of the year.

Although many of the artificial reefs documented on the southern British Columbia coast prior to 1994 were successfully colonized by marine flora and fauna, it is important to realize that several issues surrounding the creation of artificial reefs exist. For example, the placement of artificial reefs on silt or sand and shell substrates may result in the burial of benthic macrofauna such as clams, shrimps, etc. Also, artificial reefs may introduce new predators that can prey on existing fish resources. There is also the question of whether artificial reefs produce more fish or attract fish from adjacent areas. However, while these issues are important, the physical and biological assessments of artificial reefs in southern British Columbia referenced in this report did not address these issues and, hence, the resolution of these issues was deemed to be beyond the scope of this report.

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Appendix I. Species List For Fish Observed On Artificial Reefs Constructed In Southern British Columbia Prior To 1994

Common Name	Scientific Name
Herring	**Family Clupeidae**
Pacific Herring	Clupea harengus pallasi
Tubesnouts	**Family Aulorhynchidae**
Tubesnout	Aulorynchus flavidus
Surfperches	**Family Embiotocidae**
Kelp Perch	Brachyistus frenatus
Pile Perch	Rhacochilus vacca
Shiner Perch	Cymatogaster aggregata
Striped Perch	Embiotoca lateralis
Gobies	**Family Gobiidae**
Bay Goby	Lepidogobius lepidus
Blackeyed Goby	Coryphopterus nicholsi
Ronquils	**Family Bathymasteridae**
Rockfishes	**Family Scorpaenidae**
Black Rockfish	Sebastes melanops
Canary Rockfish	Sebastes pinniger
Copper Rockfish	Sebastes caurinus
Quillback Rockfish	Sebastes maliger
Greenling	**Family Hexagrammidae**
Kelp Greenling	Hexagrammos decagrammus
Lingcod	Ophiodon elongatus
Painted Greenling	Oxylebius pictus
Sculpins	**Family Cottidae**
Cabezon	Scorpaenichthys marmoratus
Longfin Sculpin	Jordania zonope
Red Irish Lord	Hemilepidotus hemilipidotus

Appendix II. Species List For Invertebrates Observed On Artificial Reefs Constructed In Southern British Columbia Prior To 1994

Common Name	Scientific Name
Sponges	
Orange Trumpet Sponge	Isodictya quatsinoensis
Anemones	
Aggregate Anemones	Anthropleura elegantissima
Painted Anemone	Urticina crassicorns
Painted Tealia Anemone	Tealia crassicornis
Plumose Anemone	Metridium senile
Hydroids	
Sea Fir Hydroid Coral	Abietinaria spp.
Hydroid	Obelia spp.
Sea Pens	
Orange Sea Pen	Ptilosarcus gurneyi
Bryozoans	
Encrusting Bryozoan	Membranipora spp.
Spiral Bryozoan	Bugula spp.
Segmented Worms	
Calcareous Tubeworm	Serpula vermicularis
Snails	
Jingle Shell	Pododesmus cepio
Nudibranchs	
Sea Lemon Nudibranch	Archidoris montereyensis
Frosted Nudibranch	Dirona albolineate
Octopus	
Pacific Octopus	Octopus dolfleini
Shrimp	
Coonstripe Shrimp	Pandalus danae
Barnacles	
Acorn Barnacle	Balanus glandula
Barnacles	Balanus spp.

Appendix II. (Continued) Species List For Invertebrates Observed On Artificial Reefs Constructed In Southern British Columbia Prior To 1994

Common Name	Scientific Name
Crabs	
Decorator Crab	Oregonia gracilis
Dungeness Crab	Cancer magister
Kelp Crab	Pugettia producta
Red Rock Crab	Cancer productus
Sea Stars	
Leather Star	Dermasterias imbricata
Morning Sun Star	Solaster dawsoni
Mottled Star	Evasterias troschellii
Ochre Star	Pisaster ochraceus
Short Spined Star	Pisaster brevispinus
Six-Rayed Stars	Leptasterias hexactis
Sunflower Star	Pycnopodia helianthoides
Sea Cucumbers	
California Sea Cucumber	Parastichopus californicus
Sea Urchins	
Green Sea Urchin	Strongylocentrotus droebachiensis
Purple Sea Urchin	Stronglyocentrotus purpuratus
Red Sea Urchin	Stronglyocentrotus franciscanus
Sea Squirts	
Ascidian	Ascidian spp.
Stalked Hairy Sea Squirt	Boltenia villosa
Transparent Sea Squirts	Corella willmeriana

Appendix III. Species List For Macroalgae Observed On Artificial Reefs Constructed In Southern British Columbia Prior To 1994

Class Chlorophyceae (Green Algae)
- Ulva spp.

Class Phaeophyceae (Brown Algae)
- Agarum cribosum
- Agarum fimbriatum
- Agarum spp.
- Bacillariophyta spp.
- Costaria costata
- Cymathere Triplicata
- Fucus spp.
- Laminaria saccharina
- Nereocystis luetkeana
- Pleurophycus gardneri
- Sargassum spp.

Class Rhodophyceae (Red Algae)
- Callophyllis spp.
- Corallina spp.
- Corallina vancouveriensis
- Dilsea spp.
- Gigartina spp.
- Griffithsia pacifica
- Iridaea spp.
- Laurencia spectabillis
- Mastocarpus spp.
- Microcladia spp.
- Neoagardhiella baileyi,
- Neoagardhiella spp.
- Polyneura spp.
- Porphyra perforata
- Rhodomenia spp.
- Rhodymenia pertusa
- Rhodymenia spp.